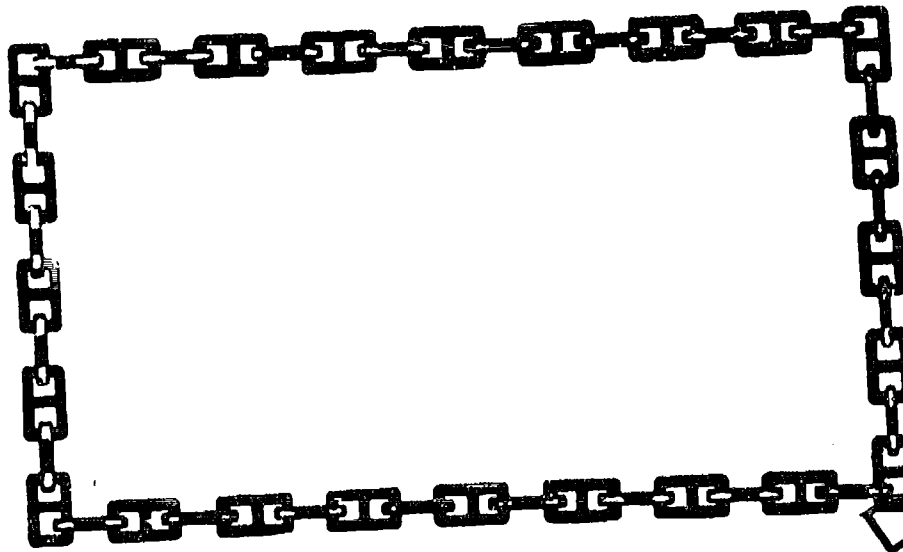


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NAVY EXPERIMENTAL DIVING UNIT
REPORT NO. 4-81 ✓

MANNED EVALUATION OF FIELD CHANGE 985 TO
THE MK-11 UBA CO₂ ABSORBENT CANISTER

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ABSTRACT

Field Change #985 to the MK-11 Semi-Closed Circuit mixed-gas UBA underwent manned evaluation at a depth of 650 FSW in 35°F water. FC 985 splits the hot water supply to the diver with part heating sheath-surrounded breathing bags and hoses and part being routed to a heat exchanger inside the CO₂ absorbant canister. The results of 6 manned canister duration studies showed that the canister effluent CO₂ was less than 1 mmHg after canister times ranging from 5 hrs 10 min to 6 hrs 2 min. This was a significant improvement over canister duration times of previous MK-11 configuration studies. A canister duration of 6 hours was assigned to the FC 985 canister. No significant differences in breathing resistance from the previous MK-11 configuration were noted. Inspired gas temperatures exceeded the minimum inspired temperature limit of 60.3°F at 650 FSW.

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INTRODUCTION

The MK-11 Semi-closed Circuit Mixed-gas Underwater Breathing Apparatus (UBA) and associated equipment was originally designed to provide complete life support and thermal protection for saturation divers to operate up to four hours in 28°F (-2.2°C) water to depths of 850 feet-of-seawater (FSW). The MK-11 diver is tethered to a diver support system by an umbilical which supplies breathing gas, hot water and communications (7). Field Change #985 (FC 985) requires the hot water supply to be split (Figure 1), with part heating sheath-surrounded breathing bags and hoses and part routed through a breathing subsystem, where it warms a canister containing a carbon dioxide absorbent bed (FC 979A). The canister effluent water then flows to a thermal protection garment, the MK-16 or NRV hot water wet suit. A previous report (1) has detailed the MK-11 function and the physiology associated with deep diving.

A number of parameters effect the ability of a diver to perform sustained work at depth while diving with this type of UBA. One of the most important of these parameters is the P_{CO_2} in the inspired gas. The P_{CO_2} is dependent upon gas flow rates, CO_2 absorbent efficiency, and the rate of CO_2 production by the working diver. The previous Field Change (FC 979A) provided a heated CO_2 absorbent canister and low resistance Koegel valves which improved the canister duration performance at 450 and 650 FSW. However, the test results were widely spread, and some upper respiratory problems were related to cold breathing gas (1).

CO_2 absorbent efficiency is dependent on its temperature and the development of a breathing bag and breathing hose sheath heated by the hot water supply (FC 985) demonstrated improved canister duration and elevated the inspired gas temperatures in unmanned studies (NCSC unpublished data, 28 July 1980) if the hot water supply could be maintained at 105°F to 110°F (40.6°C to 43.3°C) at the diver with a flow of 2.5 gallons per minute (GPM). The breathing bag sheath is configured to accept a 1 GPM flow of hot water split from the canister manifold. This hot water flows through a mesh network surrounding the breathing bags and exhausts from sheaths that extend over the hoses to the mask. This system warms the gas prior to passing through the CO_2 absorbent canister, thus raising the CO_2 absorbent temperature, and warms the gas after exiting the canister to elevate the inspired gas temperature.

The saturation dive described in this report was done to evaluate the effects of FC 985 on canister duration and flow resistance at 650 FSW in 35°F (1.7°C) water temperature. This report will present only the results comparing FC 985 to the previously evaluated FC 979A (1).

METHOD

A saturation dive with a depth profile to a maximum depth of 1000 FSW lasting 29 days was performed in the Ocean Simulation Facility (OSF) Hyperbaric Chamber Complex of the Navy Experimental Diving Unit (NEDU). The dive involved seven male divers in good physical condition, who were conditioned for 10 weeks prior to the dives by running up to 5 miles a day and a gradually increasing exercise program on a pedal ergometer.

The experiments were divided into two phases. The first phase consisted of canister duration studies and the second consisted of graded exercise studies (Table 1). All studies described in this report were performed at a chamber depth of 650 FSW with a breathing gas mixture of 95/5% helium-oxygen. UBA flow rates were adjusted for an average diver oxygen consumption (\dot{V}_{O_2}) of 2.0 l/min with a maximum P_{O_2} of 0.6 ATA and a minimum P_{O_2} of 0.4 ATA. A number 13 orifice was used to provide minimum gas loss through the cardioid valve. A 92/8% helium-oxygen mixture was supplied at a minimum flow of 42.1 SLPM with a facility regulator setting of 815 psia. Canisters were packed with 3.0 to 3.5 kg of High Performance Sodasorb (W. R. Grace Co.) just prior to each canister duration study.

Gas samples from the canister outlet, canister inlet and oronasal mask were monitored for P_{O_2} and P_{CO_2} with a mass spectrometer. Frequent mass spectrometer calibration insured an accuracy of $\pm .01\%$. A small diameter gas sample line (0.86 mm id), as designed by Thalmann et al (2), resulted in little gas sample mixing and good frequency response thereby allowing interpretation of end tidal P_{CO_2} values. In addition, diver heart rate, inspired gas temperature and rectal temperature were monitored, and oronasal differential pressure (pressure difference at the mouth from peak inspiration to peak expiration referenced to external hydrostatic pressure at the mask) was measured with a modified Validyne pressure transducer. These parameters were recorded on a multi-channel strip chart recorder.

Dive subjects exercised on a special underwater pedal ergometer (2) mounted on a vertical frame placed approximately ten feet underwater. All measurements were made during the final minute of each exercise period after steady-state had been reached. The actual work performed to overcome the combined resistance of the water, thermal garment and the ergometer increased the work load as much as 25 to 50 watts above that set on the ergometer (3, 4).

There was no way to directly measure the oxygen consumption of the diver on this dive. Previous testing of MK-16 UBA divers wearing outergarments with similar hydrodynamic resistance to those worn on this study gave measured oxygen consumptions of 1.48 l/min^{-1} during the 50 watt work cycle and 0.48 l/min^{-1} during rest (6). The mean CO_2 production for the entire canister duration study was estimated by multiplying the mean O_2 consumption by 0.90 giving an estimated mean CO_2 production of 0.98 l/min^{-1} . The mean CO_2 production during canister durations in this study was probably close to that measured during the above MK-16 study.

During graded exercise, the diver continued to exercise until he had completed the final work load or until he became fatigued. Work cycles less than 4 minutes in duration were not included in the data. Canister duration studies were terminated when canister effluent CO_2 reached 1.0% Surface Equivalent Volume (SEV) or 7.60 mmHg. Canister breakthrough was defined as that point in time when canister effluent CO_2 reached 0.5% SEV or 3.80 mmHg. Canister duration times are measured from the time the diver went "on gas" until breakthrough was achieved.

All dive subjects wore the MK-11 Mod 0 UBA with an umbilical length of 300 feet. OSF wet chamber temperature was maintained at $35^\circ \pm 2^\circ\text{F}$ ($1.7^\circ \pm 1.1^\circ\text{C}$). In order to duplicate situations of cold breathing gas, a special gas chiller at the umbilical source designed to cool inspired gas to near ambient temperature was used in all studies. Diver thermal protection was provided by an NRV hot water wet suit with flow and temperature of 1.5 GPM and 105°F to 110°F (40.6° to 43.3°C) at the diver. Approximately 1 GPM was supplied to the breathing bag sheath.

RESULTS

Six canister duration studies were completed during the dive. Canister times ranged from 5 hrs 10 min to 6 hrs 2 min, and the canister effluent CO_2 never exceeded 1 mmHg (0.13% SEV) during any of the runs. All canisters were assigned a duration of 6 hours, but would have exceeded this time if the divers could have continued.

In conjunction with the improved canister duration was an improved inspired gas temperature, with temperatures ranging from 62 to 78°F (16.7°C to 25.6°C), depending on work rate and the diver (Table 2). The divers reported the breathing gas temperature to be comfortable and there were minimal complaints of upper respiratory tract symptomology associated with this dive series. No appreciable drop in rectal temperature was noted, and all divers were able to comfortably maintain their skin temperature by operating the NRV suit bypass. However, divers reported extreme discomfort characteristically associated with the MK 11 because of facial compression and pressure points of the M-11 Face Mask. Two mechanical connection failures occurred preventing the hot water flow through the breathing bag sheath. The failure was noticed by the divers because of the reduction of breathing gas temperature. This failure thus affected the duration of the mission, but not diver safety.

Table 2 summarizes the six graded exercise studies. Peak end tidal P_{CO_2} values (P_{ETCO_2}) oronasal differential pressures and inspired gas temperatures are tabulated for all divers. These values agree with those measured for FC 979A (1).

The P_{ETCO_2} (Figure 2) increased significantly at low work rates from rest levels and then tended to level off at higher work rates. High minute ventilation did not result in elevated inspired P_{CO_2} secondary to inadequate gas residence time in the canister or CO_2 scrubbing deficiency (blowby), as inspired P_{CO_2} did not show elevation during graded exercises. Figure 3 graphs the mean oronasal differential pressure versus the work rate for all canisters at 650 FSW.

DISCUSSION

Previous studies have demonstrated substantial individual variability in response to exercise. Table 2 illustrates that some dive-subjects maintained their P_{ETCO_2} by increasing their ventilation and therefore increasing the ΔP , while others allowed an increase in P_{ETCO_2} after reaching a maximum ΔP . However, the ΔP measurements averaged for all divers have proved to be a reliable means of comparing physical changes to a diving apparatus when tested under similar conditions. There was no significant elevation of breathing resistance noted for FC 985 when compared to the averaged measurements from FC 979A (1). The average ΔP is a relative measure of total UBA breathing resistance. An accurate measurement of breathing resistance would require simultaneous measurements of both gas flows and pressure differentials (ΔP 's) in the UBA.

The MK-11 canister life expectancy with FC 985 showed no tendency toward approaching breakthrough at the 6 hour termination time and provided a six hour duration at 650 FSW and 35°F. This significant improvement in canister duration over the previously accepted central-heated core canister configuration (1) is apparently related to the increase in gas temperature entering the canister. Inspired gas temperatures meet the revised minimum standard of 60.3°F (15.7°C) at 650 FSW submitted by NEDU (5).

Overall improvement of the life support capability of the MK-11 UBA is greatest when the central-heated core canister and Koegel valves (FC 979A), and breathing bag hot water sheath (FC 985) are employed. The CO₂ scrubbing characteristics at 650 FSW are excellent with the canister offering a significant improvement in CO₂ scrubbing to depths of 650 FSW. No significant change in breathing resistance of the MK-11 system is noted with FC 985, and the breathing gas temperature is elevated to levels which enhance diver comfort and safety. Consistent canister duration studies provide a high degree of confidence in establishing the 6 hour canister duration limit in 35°F water. The M-11 Face Mask continues to be uncomfortable, possibly to the point of distraction, for long duration usage.

BIBLIOGRAPHY

1. Piantadosi, C.A., Thalmann, E.D., Spaur, W.H.: Improved Life Support Capability in The MK 11 Semi-closed Circuit UBA by Modification of The Carbon Dioxide Absorbent Canister. U.S. Navy Experimental Diving Unit Report 5-80, March 1980.
2. Thalmann, E.D., Sponholtz, D.K., Lundgren, C.E.G.: Chamber Based System for Physiological Monitoring of Submerged Exercising Subjects, Undersea Biomedical Research 5:293-300, September 1978.
3. Thalmann, E.D., Sponholtz, D.K., Lundgren, C.E.G.: Effects of Immersion and Static Lung Loading on Submerged Exercise at Depth, Undersea Biomedical Research 6(3):259-290, 1979.
4. Piantadosi, C.A., Clinton, R.L., and Thalmann, E.D.: Prolonged Oxygen Exposures in Immersed Exercising Divers at 25 FSW, Undersea Biomedical Research 6(4):347-356, 1979.
5. Piantadosi, C.A.: Respiratory Heat Loss Limits in Helium-Oxygen Saturation Diving, Navy Experimental Diving Unit Report 10-80, June 1980.
6. Gray, C. G. and E. D. Thalmann; Manned Evaluation of the Pre-production MK-16 Underwater Breathing Apparatus, Navy Experimental Diving Unit Report 13-80, August 1980.
7. "Mixed Gas Underwater Breathing Apparatus", U.S. Navy Diving Manual, Volume 2 (Change 1) Chapter 10, NAVSEA 0994-LP-001-9020, Jan 1977. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

TABLE 1

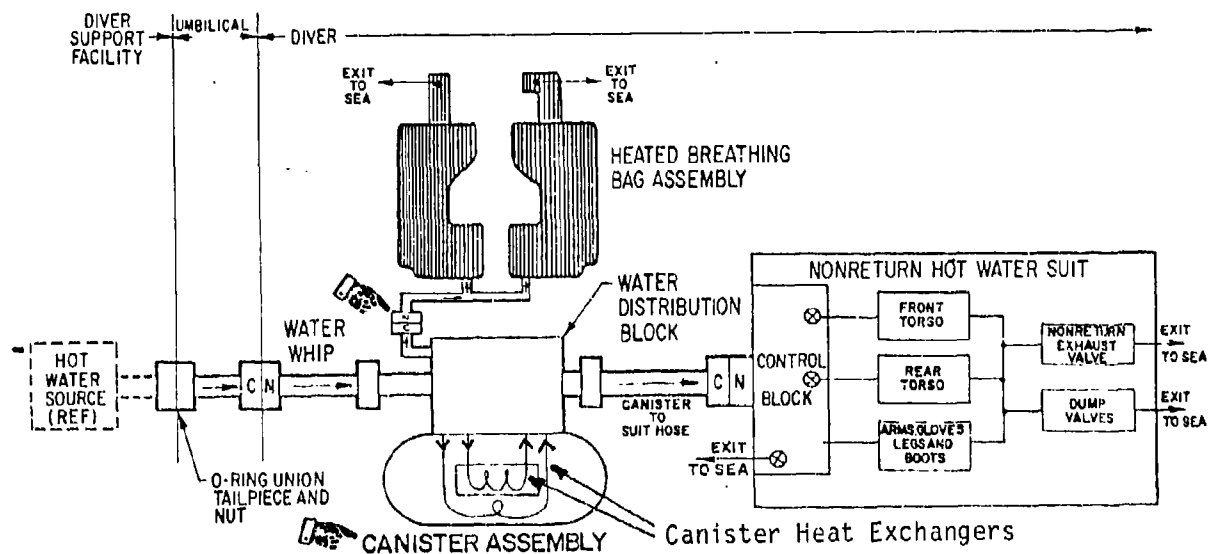
<u>STUDY</u>	<u>TIME</u>	<u>WORK RATE</u>	<u>DURATION</u>
<u>Canister Duration</u>	0 - 5 Min	Rest	5 Min
	5 - 11 Min	50 Watts	6 Min
	11 - 15 Min	Rest	4 Min
	15 - 21 Min	50 Watts	6 Min
	21 - 25 Min	Rest	4 Min
Work-Rest cycle continues until diver becomes fatigued or until the canister is exhausted, (6 hour limit).			
<u>Graded Exercise</u>	0 - 6 Min	Rest	6 Min
	6 - 12 Min	50 Watts	6 Min
	12 - 15 Min	Rest	3 Min
	15 - 21 Min	100 Watts	6 Min
	21 - 24 Min	Rest	3 Min
	24 - 30 Min	150 Watts	6 Min

TABLE 2

DIVER #	WORK RATE (Watts)	END EXPIRED PCO ₂ (PET CO ₂) (%SEV)	AVERAGE PRESSURE DIFFERENTIAL* (cm H ₂ O)	INSPIRED GAS TEMPERATURE (°F)
1	Rest	3.8	12	---
	50	5.0	19	---
	100	5.1	24	---
	150	5.0	28	---
2	Rest	6.2	14	68
	50	7.6	16	64
	100	7.8	18	68
	150	7.8	18	68
3	Rest	4.8	18	76
	50	6.0	20	75
	100	5.5	36	77
	150	6.2	33	78
4	Rest	5.0	12	64
	50	7.0	20	66
	100	7.3	18	68
	150	6.0	22	72
5	Rest	4.6	12	77
	50	6.6	27	76
	100	6.2	29	77
	150	5.8	30	78
6	Rest	5.7	11	71
	50	7.2	18	69
	100	7.0	20	70
	150	7.8	21	71

Average:	Rest	5.0 ± .8	13.2 ± 2.6	71.2 ± 5.4
	50	6.6 ± .9	20 ± 3.7	70 ± 5.3
	100	6.5 ± 1.1	24.2 ± 7.2	72 ± 4.6
	150	6.4 ± 1.1	25.3 ± 5.9	73.4 ± 4.4

*Average pressure differential is the mean of pressure from peak exhalation to peak inhalation referenced to the hydrostatic pressure at the front of the helmet.



NOTE: C INDICATES COUPLER; N INDICATES NIPPLE.

Fig. 1 HOT WATER SUPPLY SCHEMATIC FOR MK-11 UBA
FIELD CHANGE #985

Water flow is split at the water distribution block. Part goes to the heated sheath-surrounded breathing bag assembly and part to the heat exchangers inside the canister. The remaining flow is directed to the diver's NRV hot water wet suit.

FIG. 2
END TIDAL PCO_2 vs. WORK RATE
(Depth 650 FSW)

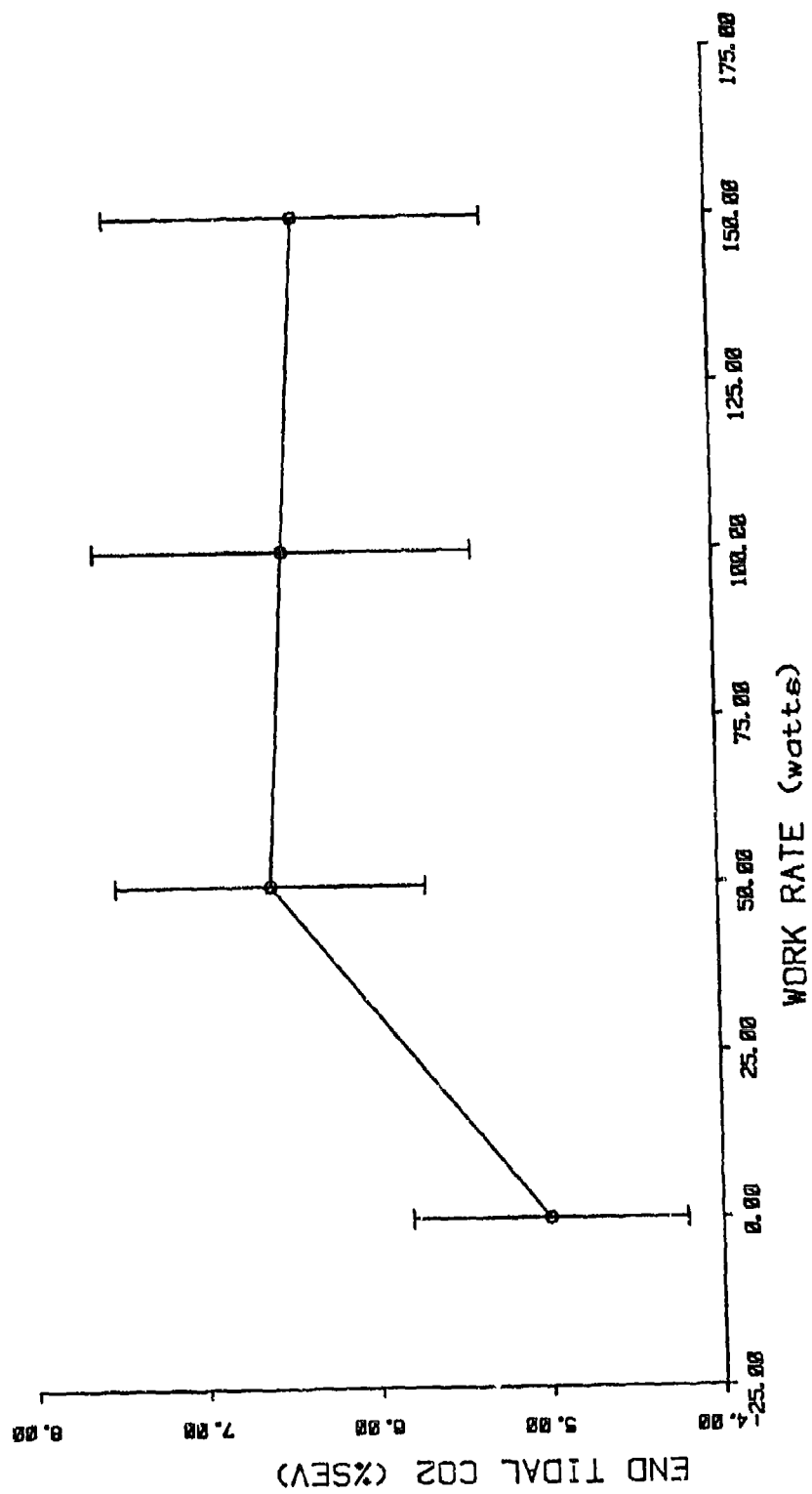


FIG. 3
 PEAK INHALATION/PEAK EXHALATION PRESSURE DIFFERENCE
 vs
 WORK RATE
 (Depth 650 FSW)

